Design of Linear Array Antenna Using Rectangular Microstrip with Corner Feeding for Base-Station of Mobile Communication Systems

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ABSTRACT

In this paper linear array antenna is presented, with elements of rectangular micro strip antenna with corner feeding offering dual-band operation (890-960) MHz GSM and (1.71-1.88) GHz DCS bands. This design is suitable for mobile communication system (base-station). In this paper, a simple technique is used for obtaining dual frequency operation for a rectangular microstrip antenna such that the length of the element resonant at one frequency and the width at another frequency. This paper is divided into three parts, the first part is related with the design of rectangular microstrip antenna with corner feeding and its performance (impedance, directivity, radiation pattern), the second part is related with design of linear array with its feed network and transformers, while the third part is related to the calculation of the base station antenna coverage.

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1-Introduction

The rapid growth of wireless and mobile communication systems has increased the demand for wider bandwidth and smaller devices. Antennas following this trend have to be compact and integrated while satisfying desired impedance behavior and radiation characteristics. Microstrip antennas find wide applications in such devices due to its light weight, low profile, planner configuration and compactness [1].

The rapid growth in the number of users of mobile communications means that many operators must find new ways of increasing the capacity of their networks. Their options include allocating more frequencies, introducing frequency- hopping techniques, and adding micro cells and adaptive antenna systems. MHz is 1.795 and 925The introduction of new frequency bands at an example of allocating frequency to increase capacity [2, 3].

Cellular networks are composed of geographically separated base stations connected to a back bone network with each base station serving on area called cell as shown in figure (1). In some systems cells are further sub divided into "sectors" and each covered its own directional antenna sited at the base station location. Operationally, each sector is treated as independent cell. Directional antennas have higher gain than omni-directional antennas, all other thing being equal. Hence the range of these sectors is generally greater than obtained with an omni-directional antenna. Sector zed cells reduce the interference by the base station of its users to the rest of the network and they are widely used for this purpose and most systems in commercial service today employ three sectors per site. The range of each base station may be from 1-3 km as the typical range of digital cellular systems [2].
In the radio position of the network, the "uplink" refers to communication from the handset "up to" the base station: the handset or user terminal is suitably digitizes and frames voice

Or packet data meant for the network. This digitized data then is modulated using digital and radio circuitry and transmitted via the antenna in the handset. The antennas and circuitry at the base station receive the radio signal, demodulate it and send the user information on to the wired network. The "down link" refers to the reverse direction, where the communication is from the base station "down to" the handset or user terminal. The base station suitably digitizes and frames voice or packet data meant for the subscriber. This digitized data is modulated using digital and radio circuitry and is transmitted via the antennas at the base station. The antenna and circuitry at the handset receive the radio signal, demodulate it and send information on to the subscriber [2].

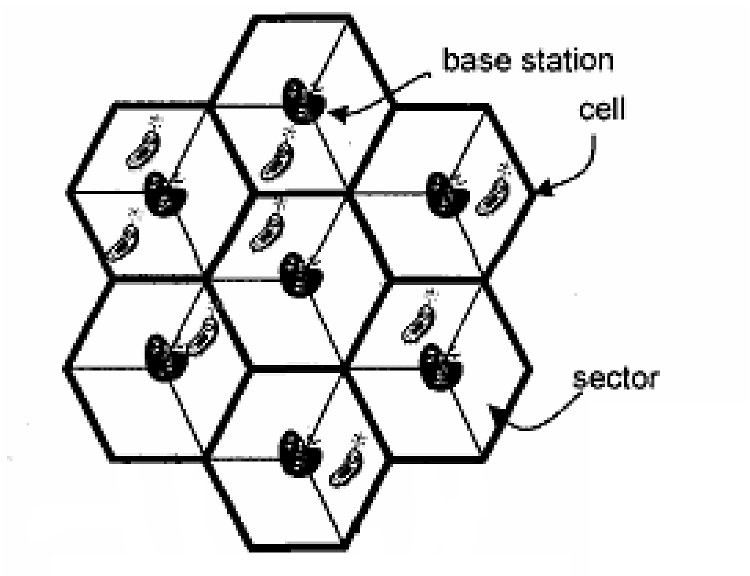


Fig. (1) Base Station Cells

2- Coverage

Coverage is the area in which communication between a mobile and the base station is possible. In sparely populated areas, extending coverage is often more important than increasing capacity. The capacity is a measure of the number of users a system can support in a given area. The approximate relation of the coverage area to antenna gain can be derived using a simple exponential path loss model, and the received power P_r , is given by[3]:

$$P_r = P_t G_t G_r P_L(d_o)\left(\frac{R}{d_0}\right)^{-\sigma} \quad \text{… (1)}$$

Where:-

P_t is the transmitter power

G_t and G_r is the transmitter and receiver gains respectively.

PL (d_o) is the free space loss at same reference distance (d_o) from the transmitter (on the order of 1 km for a cellular system)

R is the transmit-receive range

σ is the path loss exponent, which typically between 3 and 4

This model assume R≥ d_o , rearranging yields

$$R = d_0\left(\frac{P_t G_t G_r P_l(d_0)}{P_r}\right)^{1/\sigma} \quad \text{…(2)}$$

$$A_c = \pi R^2$$

Where A_c is the coverage area of the cell. Then When G is the gain of the transmitter or receiver antenna and the other held constant [3]

$$A_c \propto G^{2/\sigma}$$

3- Multiband Operation

Some novel dual–band (GSM/DCS) or (GSM/DCS/PCS) designs have also been developed. With the side spread use of the GSM system which employs the dual frequency bands of 925 MHz and 1795 MHz, multiband operation of mobile phones is advancing rapidly[4].The application of multiband systems with a variety of frequency band combinations is accelerating, whereby the intonation roaming is progressing and new functions are being added including GPS(1.57GHz) and Bluetooth (2.4 GHz)[5].

4- Rectangular Microstrip Antenna

A microstrip patch antenna consists of a very thin metallic patch placed a small fraction of a wavelength above a conducting ground-plane. The patch and ground-plane are separated by a dielectric. The patch conductor is normally copper and can assume any shape, but simple geometries generally are used, and this simplifies the analysis and performance prediction. The patches are usually photoetched on the dielectric substrate. The substrate is usually non-magnetic. The relative permittivity (e_r) of the substrate is normally in the region between 1 and 10, which enhances the fringing fields that account for radiation, but higher values may be used in special circumstances. Due to its simple geometry, the half-wave rectangular patch is the most commonly used microstrip antenna. It is characterized by its length *L*, width *w* and thickness *h*, as shown in figure (2) [6,7].

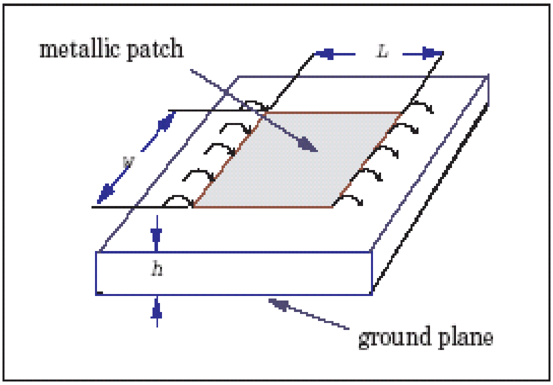


Figure (2) A square microstrip patch antenna showing fringing fields that account for radiation.

5- Designing of Patch Dimensions

5.1- Element width

The first design step is to choose a suitable dielectric substrate of appropriate thickness. For a dielectric substrate of thickness h, an antenna operating frequency of f_r, the width w is given by [7,8]:

$$w = \frac{c}{2f_r}\left(\frac{\varepsilon_r + 1}{2}\right)^{-\frac{1}{2}} \qquad \ldots 3$$

5.2- Element Length

The length of the resonant element is then obtained from [7,8].

$$L = \frac{c}{2f_r\sqrt{\varepsilon_e}} - 2\Delta L \qquad \ldots 4$$

Where

$$\Delta L = 0.412h\frac{(\varepsilon_e + 0.3)\left(\frac{w}{h} + 0.264\right)}{(\varepsilon_e - 0.258)\left(\frac{w}{h} + 0.8\right)} \quad \text{....5}$$

$$\varepsilon_e = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{12h}{w}\right)^{-\frac{1}{2}} \quad \text{...6}$$

$$E_\phi = +j\frac{2V_o e^{-j\beta r}}{\pi r}\left\{\sin\theta\frac{\sin\left(\frac{\beta w}{2}\cos\theta\right)}{\cos\theta}\right\}\cos\left(\frac{\beta L_e}{2}\sin\theta\sin\phi\right) \quad \text{...7}$$

The E-plane pattern for $(\theta = 90^o, 0 \le \phi \le 90^o \text{ and } 270 \le \phi \le 360^o)$
Is given

$$E_\phi = +j\frac{\beta W V_o e^{-j\beta r}}{\pi r}\left\{\frac{\sin\left(\frac{\beta h}{2}\cos\phi\right)}{\frac{\beta h}{2}\cos\phi}\right\}\cos\left(\frac{\beta L_e}{2}\sin\phi\right) \quad \text{...8}$$

The H-plane pattern for $(\phi = 0^o, 0 \le \theta \le 180^o)$ **is given**

$$E_\phi = +j\frac{\beta w V_o e^{-j\beta r}}{\pi r}\left\{\sin\theta\frac{\sin\left(\frac{\beta w}{2}\cos\theta\right)}{\frac{\beta w}{2}\sin\theta}\frac{\sin\left(\frac{\beta h}{2}\cos\theta\right)}{\frac{\beta h}{2}\cos\theta}\right\}\cos\left(\frac{\beta L_e}{2}\sin\theta\sin\phi\right) \quad \text{...9}$$

7- Input Impedance

Each radiating slot is represented by a parallel equivalent admittance Y_1 and Y_2 . The conductance an susceptance in each slot is equivalent, since: $G_1 = G_2$ and $B_1 = B_2$ …10

the equivalent admittance of slot 1 based on an infinitely wide uniform slot is given by:

$$G_1 = \frac{2P_{rad}}{|V_o|^2} \qquad \text{…(11)}$$

And the susceptance *B* is given by:

$$B = \frac{K_o \Delta L \sqrt{\varepsilon_e}}{Z_o} \qquad \text{...(12)}$$

Using the electric field in equation (7) the power radiation is written as:

$$P_{rad} = \frac{|V_o|^2}{2\pi\eta_o} \int_0^{\pi} \left\{ \frac{\sin\left(\frac{k_o W}{2}\cos\theta\right)}{\cos\theta} \right\}^2 \sin^3\theta \, d\theta \qquad \text{…(13)}$$

The equivalent input impedance can be calculated by transferring Y_2 from slot 2 position to slot 1 position over the transmission line of length L, then:

$$\bar{Z}_2 = Z_o \left(\frac{Z_2 + jZ_o \tan\beta L}{Z_o + j\tan\beta L} \right) \qquad \text{…(14)}$$

Where: $\bar{Z}_2$ is the transferred slot impedance of slot 2 toward slot 1

$$Z_o = \frac{\eta_o}{\sqrt{\varepsilon_e}} \frac{h}{W_e} \qquad \ldots(15)$$

W_e is the effective width due to the stray field and given by:

$$W_e = \frac{2\pi h}{\ln\left\{ \frac{hF}{T} + \sqrt{1 + \left(\frac{2h}{T}\right)^2} \right\}} \qquad \ldots(16)$$

$$F = 6 + (2\pi - 6)\exp\left\{ -\frac{4\pi^2}{3}\left(\frac{h}{T}\right)^{\frac{3}{4}} \right\} \qquad \ldots(17)$$

$$T = W + \frac{t}{\pi}\left\{ 1 + \ln\left(\sqrt{\frac{4}{\left(\bar{t}/h\right)^2 + \frac{(1/\pi)^2}{\left(W/\bar{t}\right) + 1.1^2}}} \right) \right\} \qquad \ldots(18)$$

t is the conductor thickness. And the mutual conductance is given by:

$$G_{12} = \frac{1}{|V_o|^2} \operatorname{Real} \iint E_1 \times H_2^* . ds \qquad \ldots(19)$$

And

$$Z_{in} = Z_1 // \bar{Z}_2 \qquad \ldots(20)$$

Where Z_{in} Input impedance at the center. Now the input impedance at the corner is given by transferring Z_{in} by distance w/2

$$\bar{Z}_{inc} = Z_o \left(\frac{\bar{Z}_{in} + jZ_o \tan \beta w/2}{Z_o + j\tan \beta w/2} \right) \qquad \ldots(21)$$

8- Antenna Matching

Matching is usually required between the antenna and the feed line, because antenna input impedance differ from customary 50 ohm. line standard impedance. An appropriately selected port location (tapered line) will provide matching between the antenna and its feed line.

In transmission line theory, the only reason for reflection is the change in impedance. For a non-uniform line, with a length l as a matching section inserted between two different impedances Z_1 and Z_2, the input reflection coefficient (Γ) of matching section is given by [10]:

$$\Gamma = \int_{-\frac{l}{2}}^{\frac{l}{2}} \frac{d\mathrm{Ln}\left(Z_o(x)\right)}{dx} e^{-j2\beta x} dx \qquad \ldots(22)$$

This relationship can be inverted by the theory of Fourier transform to obtain:

$$\frac{d\mathrm{Ln}\left(Z_o(x)\right)}{dx} = \frac{1}{\pi} \int_{-\infty}^{\infty} \Gamma e^{jB} e^{j2B} d\beta \qquad \ldots(23)$$

One of the important taper is the exponential form which has broad-band operation and have the following form [10]:

$$Z_o(x) = \sqrt{Z_1 Z_2}\left(\frac{Z_1}{Z_2}\right)^{\frac{x}{l}} \qquad \ldots(24)$$

9-Directivity

The directivity of a single slot can be expressed as given by [8]:

$$D_o = \left(\frac{2\pi W}{\lambda_o}\right)\frac{1}{I_1} \qquad \ldots(25)$$

Where

$$I_1 = \int_0^{\pi}\left[\frac{\sin\left(\frac{\beta W}{2}\cos\theta\right)}{\cos\theta}\right]^2 \sin^3\theta \, d\theta \qquad \ldots(26)$$

For two slots, the directivity can be written as:

$$D_2 = \left(\frac{2\pi W}{\lambda_o}\right)^2 \frac{\pi}{I_2} = \frac{2}{15G_{rad}}\left(\frac{W}{\lambda_o}\right) \qquad \ldots(27)$$

Where G_{rad} is the radiation conductance and

$$I_2 = \int_0^{\pi}\int_0^{\pi}\left[\frac{\sin\left(\frac{\beta W}{2}\cos\theta\right)}{\cos\theta}\right]^2 \sin^3\theta \cos^2\left[\frac{\beta L_e}{2}\sin\theta\sin\phi\right] d\theta \, d\phi \qquad \ldots(28)$$

10- Results and Discussion

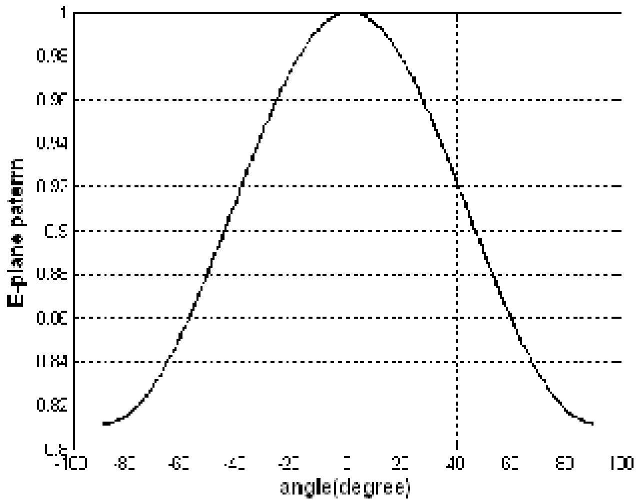
10.1- Design of Dual Band Microstrip Antenna

The design of a dual band microstrip antenna is made, with the antenna designed to be used for mobile telecommunications. It is aimed to design an antenna which had low loss due to impedance mismatch in the bands 890 MHz to 960 MHz and 1.71GHz to 1.88 GHz, low cross polarization, single beam radiation pattern and high efficiency over these frequency bands. To get a dual band antenna a corner fed rectangular patch antenna is used, that it has low cross polarization level (no parasite elements or multilayers).

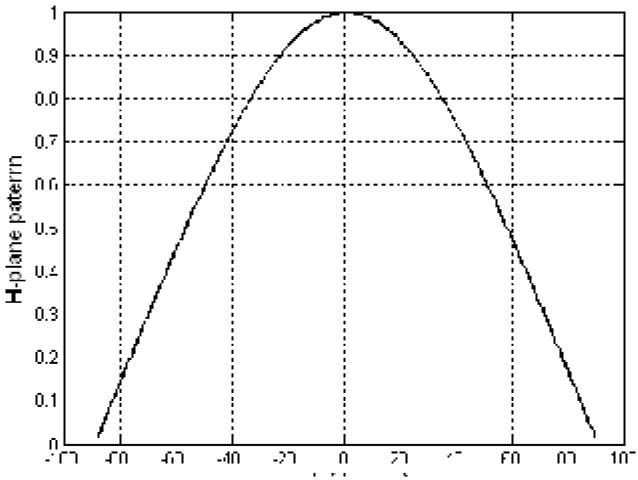
Table (1) shows the effect of the variation of the patch dimensions (L and W) on the frequencies f_1 and f_2 respectively. It can be seen that for f_1=925 MHz (first resonant frequency) and f_2=1.795 MHz (second resonant frequency), the choosen length and width of the patch is:

L=3.29cm and W=4.09 cm.

Figure (3) and figure (4) show the E-plane and H-plane pattern for rectangular microstrip antenna with corner feeding. Figure (5) shows the variation of the VSWR with respect to the frequency for corner fed point. Figure (6) shows the characteristics of the input impedance frequency response with corner fed point.



Fig(3) E-plane pattern for rectangular microstrip antenna with corner feeding



Fig(4) H-plane pattern for rectangular microstrip antenna with corner feeding

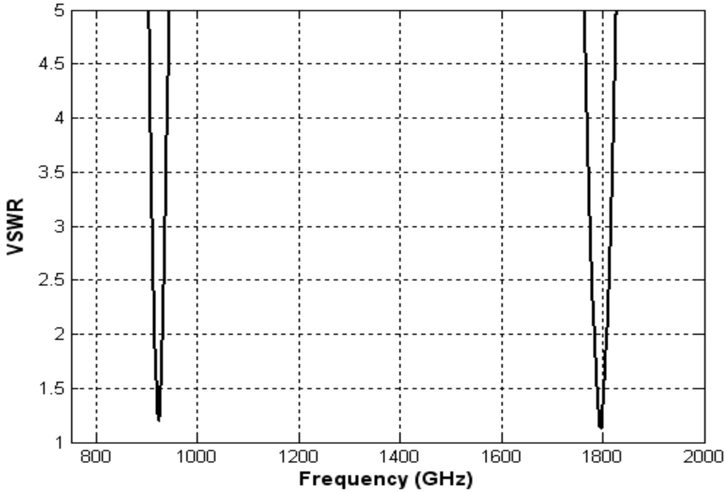


Figure (5) Input VSWR Frequency Response

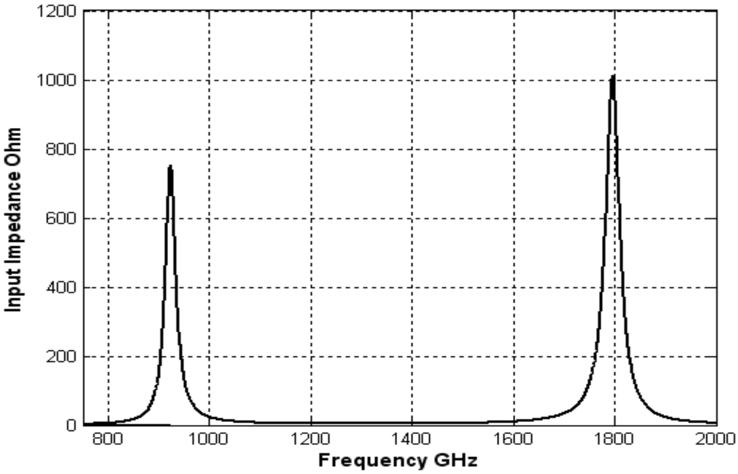


Figure (6) Input Impedance Frequency Response

Table (1) Resonance frequencies variation with respect to Patch Dimension

W=4				
L	f_1GHz	f_2GHz	Z_1	Z_2
2.9	1.006	1.896	812	948
2.95	0.996	1.886	799	964
3	0.985	1.877	790	979
3.05	0.975	1.867	780	992
3.1	0.965	1.858	771	1005
3.15	0.956	1.849	762	1016.5
3.2	0.946	1.839	756	1027
3.25	0.973	1.83	748	1035
3.29	0.929	1.822	742	1042
3.325	0.923	1.815	739	1050
3.35	0.918	1.811	734	1049
3.4	0.91	1.8	730	1050
3.45	0.9	1.791	723	1057
3.5	0.892	1.782	719	1058
3.6	0.857	1.762	709	1059

W=4.09				
L	f_1GHz	f_2GHz	Z_1	Z_2
2.9	0.999	1.867	831	909
2.95	0.989	1.858	818	925
3	0.979	1.849	806	941
3.05	0.969	1.84	796	955
3.1	0.959	1.831	787	969
3.15	0.95	1.822	776	982
3.2	0.959	1.831	787	969
3.25	0.931	1.804	761	1004
3.29	0.925	1.795	754	1011
3.325	0.917	1.79	750	1017
3.35	0.913	1.786	747	1020
3.4	0.904	1.776	740	1027
3.45	0.895	1.767	734	1033
3.5	0.887	1.758	729	1037
3.6	0.87	1.74	718	1040

W=4.1				
L	f_1GHz	f_2GHz	Z_1	Z_2
2.9	0.998	1.864	833	904
2.95	0.988	1.855	821	921
3	0.978	1.846	810	936
3.05	0.968	1.837	798	951
3.1	0.958	1.828	788	966
3.15	0.949	1.819	779	978
3.2	0.939	1.81	770	990
3.25	0.93	1.801	763	1000
3.29	0.923	1.794	756	1008
3.325	0.917	1.787	751	1014
3.35	0.912	1.783	748	1017
3.4	0.903	1.774	742	1025
3.45	0.895	1.765	736	1030
3.5	0.886	1.755	730	1034
3.6	0.87	1.737	720	1038

W=4.2				
L	f_1GHz	f_2GHz	Z_1	Z_2
2.9	0.99	1.834	857	862
2.95	0.98	1.825	843	979
3	0.97	1.817	830	895
3.05	0.961	1.808	817	911
3.1	0.951	1.799	807	925
3.15	0.942	1.79	797	938
3.2	0.933	1.782	786	952
3.25	0.924	1.773	77.5	964
3.29	0.916	1.766	771	972
3.325	0.91	1.760	766	980
3.35	0.906	1.756	762	984
3.4	0.897	1.747	755	993
3.45	0.889	1.738	748	1000
3.5	0.881	1.73	741	1006
3.6	0.614	1.712	731	1015

W=4.3				
L	f_1GHz	f_2GHz	Z_1	Z_2
2.9	0982	1.806	882	821
2.95	0.972	1.797	865	838
3	0.963	1.788	852	855
3.05	0.953	1.78	839	870
3.1	0.944	1.771	827	886
3.15	0.935	1.763	815	900
3.2	0.926	1.754	806	913
3.25	0.917	1.746	796	927
3.29	0.91	1.739	788	936
3.325	0.904	1.734	782	943.5
3.35	0.9	1.728	777	950
3.4	0.891	1.721	769	960
3.45	0.883	1.713	762	968
3.5	0.875	1.704	775	976
3.6	0.86	1.687	740	988

W=4.4				
L	f_1GHz	f_2GHz	Z_1	Z_2
2.9	0.974	1.778	908	782
2.95	0.965	1.769	891	799
3	0.955	1.761	876	816
3.05	0.946	1.753	862	831
3.1	0.937	1.744	849	847
3.15	0.928	1.736	835	863
3.2	0.919	1.728	825	876
3.25	0.91	1.72	813	890
3.29	0.904	1.713	805	900
3.325	0.898	1.708	798	909
3.35	0.89	1.699	790	915
3.4	0.885	1.696	785	926
3.45	0.877	1.688	777	936
3.5	0.869	1.68	770	946
3.6	0.853	1.664	755	960

W=4.5				
L	f_1GHz	f_2GHz	Z_1	Z_2
2.9	0.966	1.751	936	745
2.95	0.957	1.743	918	761
3	0.948	1.735	901	778
3.05	0.939	1.727	886	794
3.1	0.93	1.717	872	810
3.15	0.921	1.71	858	826
3.2	0.912	1.7	845	840
3.25	0.904	1.695	834	855
3.29	0.897	1.688	825	864
3.325	0.891	1.683	817	874
3.35	0.885	1.677	810	884
3.4	0.879	1.671	803	892
3.45	0.871	1.664	793	900
3.5	0.863	1.656	785	914
3.6	0.848	1.64	769	930

W=4.6				
L	f_1GHz	f_2GHz	Z_1	Z_2
2.9	0.985	1.726	966	709
2.95	0.949	1.718	946	726
3	0.94	1.71	928	742
3.05	0.931	1.702	911	758
3.1	0.923	1.694	896	774
3.15	0.914	1.686	881	789
3.2	0.906	1.678	867	804
3.25	0.897	1.67	854	818
3.29	0.891	1.664	845	830
3.325	0.885	1.659	837	839
3.35	0.873	1.647	821	858
3.4	0.869	1.643	815	864
3.45	0.865	1.64	811	870
3.5	0.857	1.632	800	881
3.6	0.842	1.618	784	901

W=4.7				
L	f_1GHz	f_2GHz	Z_1	Z_2
2.9	**0.95**	**1.702**	**995**	**675**
2.95	**0.942**	**1.694**	**976**	**691**
3	**0.933**	**1.685**	**957**	**708**
3.05	**0.924**	**1.677**	**939**	**723**
3.1	**0.916**	**1.67**	**922**	**740**
3.15	**0.907**	**1.662**	**906**	**755**
3.2	**0.899**	**1.654**	**891**	**770**
3.25	**0.981**	**1.647**	**877**	**784**
3.29	**0.884**	**1.641**	**866**	**796**
3.325	**0.879**	**1.635**	**858**	**805**
3.35	**0.867**	**1.624**	**840**	**825**
3.4	**0.862**	**1.620**	**835**	**829**
3.45	**0.859**	**1.617**	**829**	**837**
3.5	**0.852**	**1.61**	**818**	**850**
3.6	**0.837**	**1.595**	**800**	**870**

W=4.8				
L	f_1GHz	f_2GHz	Z_1	Z_2
2.9	**0.942**	**1.679**	**1029**	**642**
2.95	**0.934**	**1.67**	**1008**	**660**
3	**0.925**	**1.662**	**987**	**675**
3.05	**0.917**	**1.655**	**968**	**691**
3.1	**0.909**	**1.647**	**948**	**703**
3.15	**0.9**	**1.639**	**930**	**722**
3.2	**0.892**	**1.631**	**915**	**736**
3.25	**0.884**	**1.624**	**900**	**751**
3.29	**0.878**	**1.618**	**890**	**762**
3.325	**0.873**	**1.613**	**878**	**772**
3.35	**0.861**	**1.602**	**861**	**792**
3.4	**0.857**	**1.6**	**852**	**798**
3.45	**0.853**	**1.595**	**847**	**805**
3.5	**0.846**	**1.588**	**838**	**818**
3.6	**0.816**	**1.574**	**831**	**841**

W=4.9				
L	f_1GHz	f_2GHz	Z_1	Z_2
2.9	**0.934**	**1.657**	**1062**	**612**
2.95	**0.926**	**1.648**	**1042**	**622**
3	**0.918**	**1.64**	**1019**	**644**
3.05	**0.91**	**1.632**	**995**	**659**
3.1	**0.902**	**1.625**	**976**	**674**
3.15	**0.894**	**1.617**	**958**	**690**
3.2	**0.886**	**1.609**	**941**	**704**
3.25	**0.878**	**1.602**	**926**	**719**
3.29	**0.872**	**1.596**	**913**	**731**
3.325	**0.866**	**1.591**	**903**	**740**
3.35	**0.855**	**1.581**	**833**	**761**
3.4	**0.848**	**1.575**	**850**	**770**
3.45	**0.846**	**1.572**	**867**	**776**
3.5	**0.84**	**1.567**	**857**	**786**
3.6	**0.826**	**1.553**	**835**	**810**

W=3				
L	f_1GHz	f_2GHz	Z_1	Z_2
2.9	**1.088**	**2.266**	**680**	**1291**
2.95	**1.075**	**2.249**	**678**	**1266**
3	**1.063**	**2.231**	**677**	**1241**
3.05	**1.051**	**2.213**	**675**	**1213**
3.1	**1.039**	**2.195**	**674**	**1183**
3.15	**1.028**	**2.177**	**673**	**1151**
3.2	**1.018**	**2.159**	**672**	**1119**
3.25	**1.005**	**2.14**	**672**	**1086**
3.29	**0.997**	**2.126**	**672.5**	**1060**
3.325	**0.989**	**2.113**	**672.75**	**1038**
3.35	**0.979**	**2.086**	**672.75**	**989**
3.4	**0.974**	**2.072**	**673**	**971**
3.45	**0.964**	**2.068**	**673.5**	**958**
3.5	**0.954**	**2.05**	**674**	**925**
3.6	**0.944**	**2.043**	**675**	**911**

W=3.1				
L	f_1GHz	f_2GHz	Z_1	Z_2
2.9	1.079	2.226	686	1289
2.95	1.067	2.21	684	1273
3	1.055	2.193	681	1253
3.05	1.043	2.177	679	1232
3.1	1.031	2.16	677	1208
3.15	10.02	2.143	676	1182
3.2	1.009	2.126	675	1154
3.25	0.998	2.109	674	1125
3.29	0.989	2.185	673	1102
3.325	0.976	2.169	672.5	1082
3.35	0.973	2.152	672	1066
3.4	0.97	2.136	671.5	1045
3.45	0.965	2.136	671	1026
3.5	0.96	2.12	670	1012
3.6	0.956	2.102	670	1011

W=3.2				
L	f_1GHz	f_2GHz	Z_1	Z_2
2.9	1.07	2.186	595	1274
2.95	1.059	2.717	690	1264
3	1.047	2.156	687	1252
3.05	1.035	2.141	685	1236
3.1	1.024	2.125	682	1219
3.15	1.013	2.11	680	1199
3.2	1.002	2.094	678	1177
3.25	0.991	2.078	678	1154
3.29	0.983	2.065	676	1134
3.325	0.975	2.054	675	1115
3.35	0.96	2.03	674	1076
3.4	0.95	2.014	674	1047
3.45	0.941	1.998	673	1019
3.5	0.922	1.966	673	963
3.6	0.92	1.96	672.5	960

W=3.3				
L	f_1GHz	f_2GHz	Z_1	Z_2
2.9	1.06	2.166	512	1266
2.95	1.048	2.1	535	1252
3	1.037	1.998	584	1241
3.05	1.025	1.966	612	1226
3.1	1.013	1.924	632	1210
3.15	1.01	1.911	644	1185
3.2	0.992	1.8989	645	1165
3.25	0.99	1.877	646	1143
3.29	0.98	1.851	646	1126
3.325	0.975	1.835	646	1105
3.35	0.97	1.817	646.5	1066
3.4	0.9675	1.81	647	1040
3.45	0.941	1.799	647	1015
3.5	0.922	1.784	647	1005
3.6	0.92	1.777	648	966

W=3.5				
L	f_1GHz	f_2GHz	Z_1	Z_2
2.9	1.04	2.154	488	1259
2.95	1.039	1.999	504	1244
3	1.029	1.990	526	1234
3.05	1.015	1.955	580	1220
3.1	1.007	1.913	613	1205
3.15	0.995	1.902	635	1177
3.2	0.988	1.891	635	1155
3.25	0.980	1.826	635	1133
3.29	0.972	1.844	635	1118
3.325	0.969	1.826	635.5	1088
3.35	0.962	1.811	635.5	1054
3.4	0.955	1.799	635.5	1033
3.45	0.935	1.787	636	1010
3.5	0.918	1.779	636	984
3.6	0.911	1.72	636	954

W=3.7				
L	f_1GHz	f_2GHz	Z_1	Z_2
2.9	**1.035**	**2.148**	**481**	**1248**
2.95	**1.029**	**1.992**	**495**	**1240**
3	**1.022**	**1.985**	**518**	**1228**
3.05	**1.010**	**1.948**	**572**	**1215**
3.1	**0.998**	**1.907**	**606**	**1200**
3.15	**0.987**	**1.899**	**625**	**1166**
3.2	**0.981**	**1.887**	**630**	**1145**
3.25	**0.972**	**1.822**	**633**	**1123**
3.29	**0.966**	**1.838**	**633**	**1111**
3.325	**0.960**	**1.822**	**633**	**1080**
3.35	**0.959**	**1.802**	**635.3**	**1044**
3.4	**0.948**	**1.795**	**633.5**	**1026**
3.45	**0.929**	**1.782**	**634**	**1000**
3.5	**0.910**	**1.777**	**634**	**980**
3.6	**0.902**	**1.699**	**634**	**951**

W=3.9				
L	f_1GHz	f_2GHz	Z_1	Z_2
2.9	**1.028**	**2.143**	**466**	**1248**
2.95	**1.022**	**1.988**	**481**	**1240**
3	**1.017**	**1.980**	**502**	**1228**
3.05	**1.003**	**1.944**	**555**	**1215**
3.1	**0.992**	**1.901**	**593**	**1200**
3.15	**0.981**	**1.893**	**613**	**1166**
3.2	**0.977**	**1.881**	**619**	**1145**
3.25	**0.966**	**1.815**	**621**	**1123**
3.29	**0.959**	**1.826**	**623**	**1111**
3.325	**0.953**	**1.814**	**625**	**1080**
3.35	**0.953**	**1.798**	**625**	**1044**
3.4	**0.942**	**1.791**	**625**	**1026**
3.45	**0.923**	**1.777**	**625.5**	**1000**
3.5	**0.905**	**1.772**	**625.5**	**980**
3.6	**0.898**	**1.695**	**626**	**951**

10.2- Design of Linear Phase Array at Uniform Distribution

10.2.1- Distance Between Elements

Fig.(7) shows the variation of the array directivity with respect to distance spacing between the elements. It can be seen that, the directivity increases somewhat with spacing and then after reaching a peak at just short of full-wavelength spacing, rather abruptly decrease to a value at full-wavelength that is equal to at half-wavelength. The distance equals or greater than wavelength can not be used because grating lobes occur. The choice of distance is limited in range ($0.5\lambda<d<\lambda$). Therefore, the distance (d) is chosen to be 0.7λ.

Figures (8) and (9) show array factor pattern and total array pattern for linear array with 8- elements (as an example) and distance 0.7λ . Figure (10) shows the relation between the directivity and the range, it is noticed that when increasing the directivity the range is increased.

10.2.2- Directivity

It is found that the directivity for array factor is (10.3581 dB) and the directivity of rectangular microstrip antenna with corner feeding is equal to (6.7609 dB), and then the total directivity (directivity of array factor dB+ directivity of microstrip antenna dB) is equal to (17.119 dB).

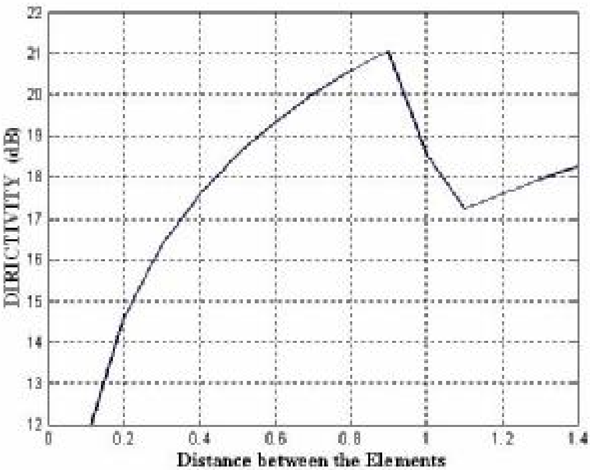


Fig.(7) Relation between directivity and space between elements

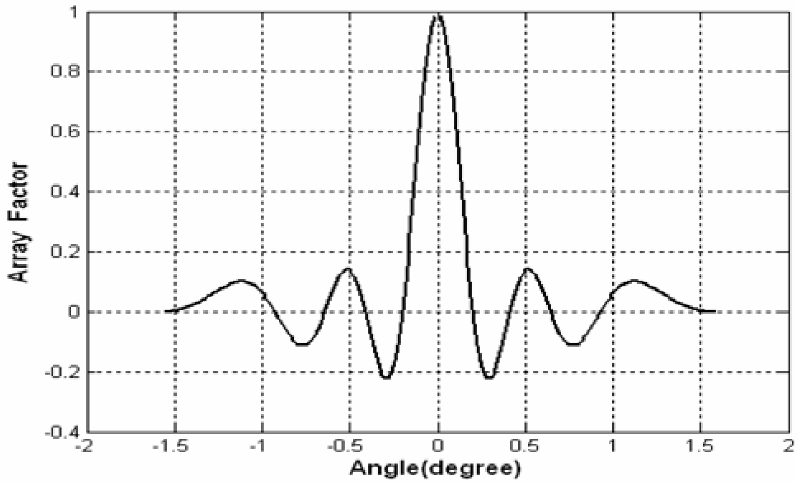


Fig.(8)Array factor for 8- elements

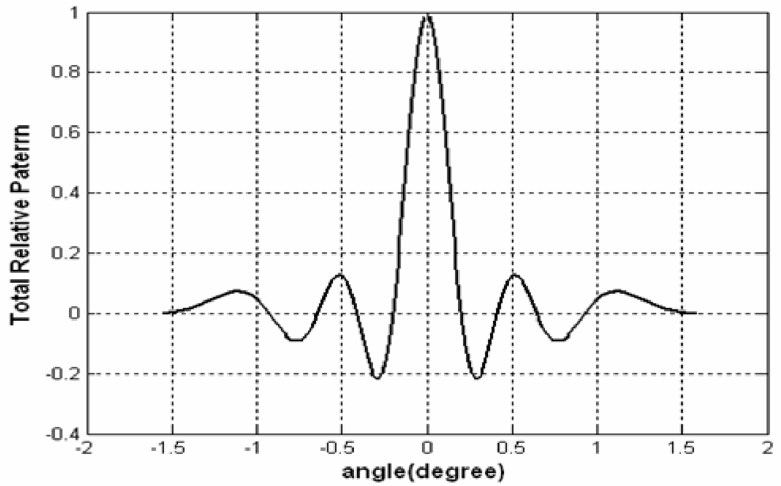


Fig.(9)Total pattern for linear array of microstrip antenna with corner feeding

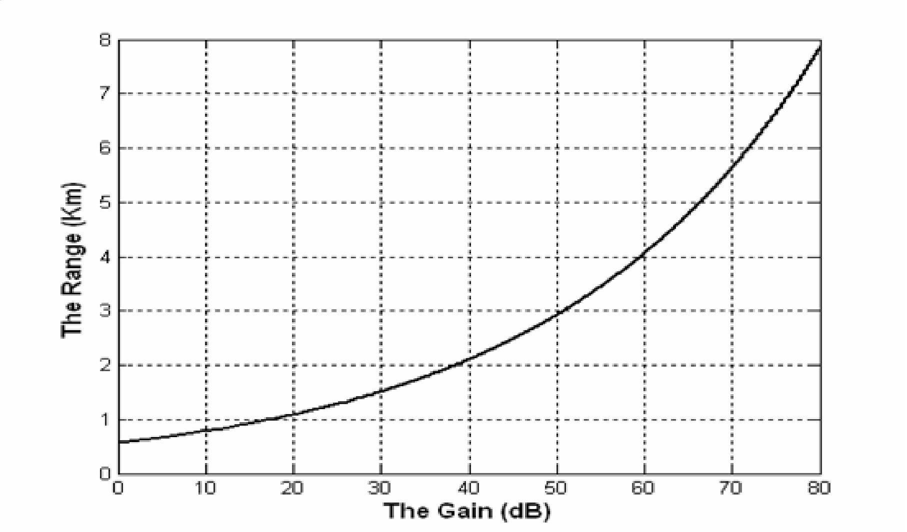
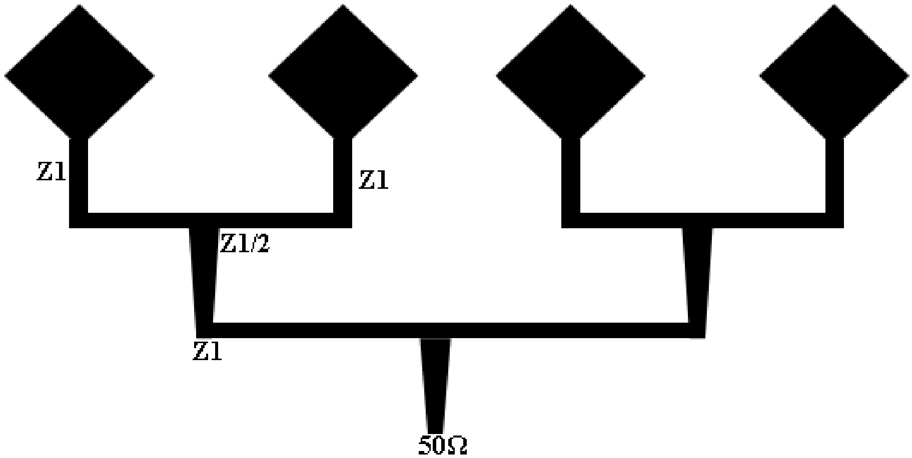


Fig.(10) Relation between the gain and the range

10.2.3- Arrays and Networks

Microstrip antennas are used not only as single elements but are very popular in arrays. Arrays are very versatile and are used, among other things, to synthesize a required pattern that can not be achieved with a single element. In addition, they are used to scan the beam of an antenna system, increase the directivity, and perform various other functions which would be difficult with any one single line, as shown in figure (11) is referred to as corporate- feed network.

The corporate- feed network is used to provide power splite of 2n (i.e, n=2, 4, 8, 16, 32, etc). This is accomplished by using taper lines, as shown in figure (12), to match (882Ω) patch elements to a (50 Ω) input. The number of elements that is used in this paper is equal to 8 elements.



Figure(11) corporate- feed network

10.2.4- Exponential Transformer

In this subsection two exponential transformers are designed. An 882Ω to 441Ω transformer is designed to be used in the array feed network as a power divider. On the other hand 441Ω to 50Ω transformer is designed to match the array with 50Ω feed line as shown in the fig.(12). Each transformer has one wavelength length and the impedance transformation is shown in figure (12). Figure (13) shows their frequency response.

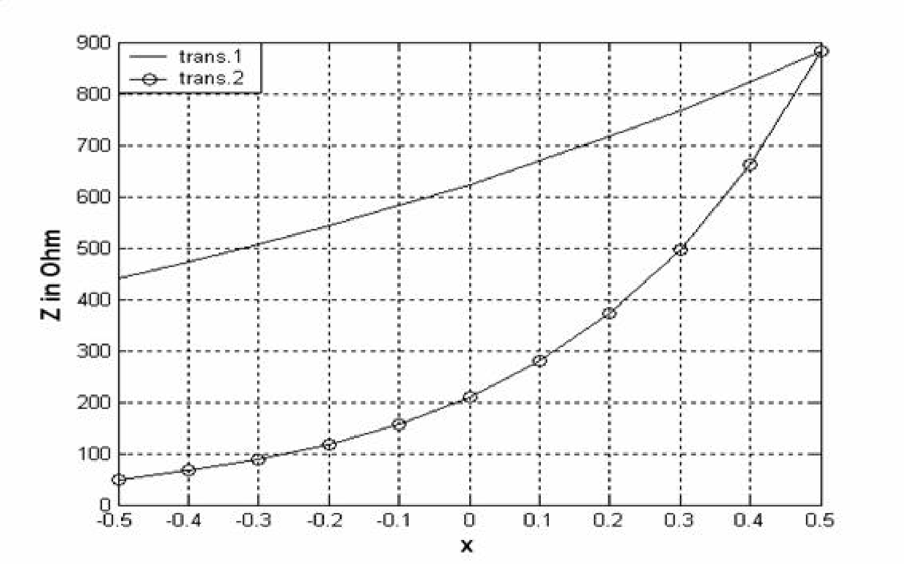


Fig. (12) variation of The Transformer Impedance w.r.t its Length

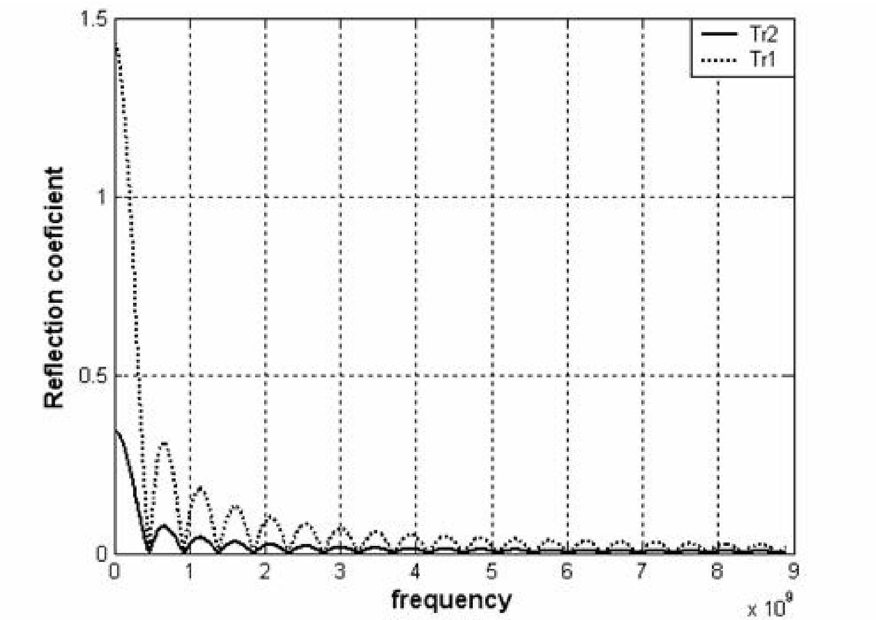


Fig. (13) Reflection Coefficient Variation w.r.t Frequency

11-Conclusion

In this paper, the design of linear phase array antenna for base station of mobile communication with 8-elements using rectangular microstrip antenna with corner feeding is achieved which offer dual-band frequency operation at 925 MHz 1.795GHz. In this paper input impedance for rectangular microstrip antenna with corner feeding is derived, and the exponential transformer is used to match between the antenna and the feed line. It is found that the range of coverage is equal to 1 Km corresponding to the directivity of the array of 17.119 dB.

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تصميم مصفوفة هوائيات باستخدام هوائي شريطي دقيق مستطيل الشكل ذات تغذية زاوية للمحطات الرئيسة لأنظمة النقال

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المستخلص

في هذا البحث تم تصميم مصفوفة الهوائيات الخطية ذات عناصر مربعة شريطية وذات تغذية عند الزاوية التي تعطي حزمتي تشغيل، الحزمة الأولىGSM(960-890) والحزمة الثانية DCS(1.88-1.71) .هذا التصميم يكون مناسب لأنظمة الأتصالات المتنقلة(المحطات–الرئيسة).في هذا البحث استخدمت تقنية بسيطة للحصول على حزمتي تشغيل باستخدام هوائي شريطي مستطيل بحيث ان طول العنصر مصمم بتردد الأول والعرض مصمم بالتردد الآخر .وقد قسم البحث الى ثلاثة اجزاء ،الجزء الأول يتعلق بتصميم هوائي شريطي مربع ذو تغذية عند الزاوية ومواصفاتة(ممانعة، توجيهية،شكل الأشعاع)،والجزء الثاني يتعلق بتصميم مصفوفة الهوائيات الخطية مع شبكة التغذية ، بينما الجزء الثالث يتعلق بحساب مدى التغطية للمحطات الرئيسة.

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