Designing and Constructing a TV Combiner Using Phase Line Method

ABBAS ALI LOTFI NEYESTANAK
Electrical Engineering
Iran University of Science & Technology
Narmak, Tehran
I.R.IRAN
r

FARROKH HOJJAT KASHANI
Electrical Engineering
Iran University of Science & Technology
Narmak, Tehran
I.R.IRAN
.

ALI HOMAII
Electrical Engineering
Islamic Azad University
Baranch of Ray
Ghom High Way, Tehra
I.R.IRAN

Abstract: - TV combiner is a device which can be used to transmit two or more TV or FM programs with different frequencies and power levels by a single wide band antenna simultaneously. One of the following three methods is usually used for its construction: 1-Star Point Filters, 2-Directional Coupler Filters and 3-Phase Line Method. In this paper, using phase line method which is simpler compared to other mentioned methods, we have designed and constructed a sample two-way 200w TV combiner in UHF band. The constructed device has shown satisfactory performance in testing and measurements and also in real-world operation.

Key-Words: - TV Combiner, Directional Coupler, Phase Line, HPHFSS, UHF.

1 Introduction

Nowadays, TV combiners are used in virtually every TV station which broadcasts more than one program, since that results in optimum usage of antenna, its supporting tower and supply system. Different kinds of TV combiners are depicted in figures 1(a) to 1(c). These combiners can be used for UHF and VHF TV bands and also for FM radio band [1]. As is evident in the figures, existing filters in directional coupler filter method in phase line approach have been replaced by a single phase line and that accounts for its simplicity and cheapness. Host of useful information about 3-dB directional coupler designing and matched load are provided in references [2] to [6]. Required phase line can be readily chosen using the information provided in [7]. This method is inflexible in terms of regulation but a suitable phase line can be chosen to use other frequencies. This combiner has been used extensively in frequency bands of 4 and 5 in Germany. In this paper, according to the information provided in the aforementioned references a new phase line TV combiner, in terms of coupler type, has been designed and constructed.

2-Phase Line Combiner

This type of combiner is shown in figure 1-c. For obtaining the phase line length, according to the following three facts that: 1- there is a 90-degree difference in phase between two output ports of 3-db symmetrical directional couplers, 2- f1 and f2 signals' phase change in two possible paths for reaching the antenna and 3- by including the phase line, signals will reach the antenna with the same phase, one can write:

Phase change of the transmitter with f1 frequency is:

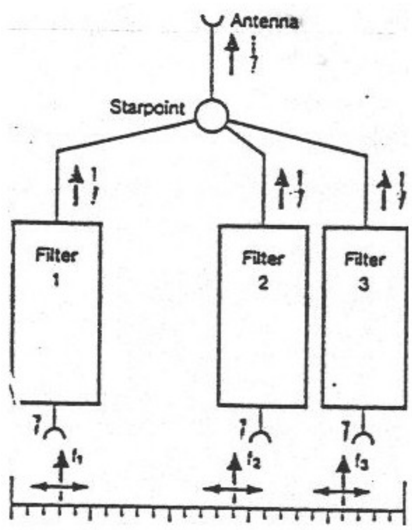

Fig.1.a. Star point combiner

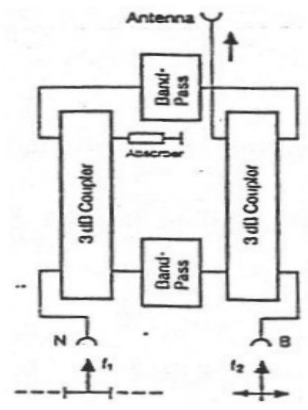

Fig.1.b. Directional filter combiner

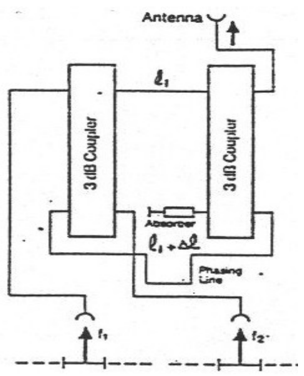

Fig.1.c. Phase line combiner

$$\begin{Bmatrix} \phi_1 \\ 180 \end{Bmatrix} \Rightarrow \phi_1 = (2k-1)\pi \qquad k \in Z \qquad (1)$$

Phase change of the transmitter with f2 frequency is:

$$\begin{Bmatrix} \phi_2 + 90 \\ 90 \end{Bmatrix} \Rightarrow \phi_2 = (2k)\pi \qquad k \in Z \qquad (2)$$

Since the phase line length is the same for both frequencies:

$$\phi = \beta \Delta l \Rightarrow \frac{\phi_1}{\beta_1} = \frac{\phi_2}{\beta_2} \Rightarrow \frac{(2k-1)\lambda_1}{2} = \frac{2k\lambda_2}{2}$$

$$\Rightarrow k = \frac{f_2}{2(f2 - f1)} \qquad (3)$$

In the above equation, λ_1 and λ_2 are wavelengths in the central frequencies of f_1 and f_2 respectively.

Now we choose k', the nearest number to k ($k', k \in Z$), and then calculate the required phase line length with the following relation:

$$\Delta l = \frac{k'c'}{f_2} \Rightarrow l_2 = l_1 + \Delta l \qquad (4)$$

In the above relation, c' is the velocity of wave in the cable with relative dielectric coefficient of ε_r and l_1 is the length of the cable in the path without phase line.

3 3dB directional quarter wavelength coupler

For designing the 3-dB directional coupler, a re-which is shown in figure 2, has been used. This type of coupler has the following properties:

1- It has relatively simple design equations.

2- It's been empirically inferred that the end of it van be attached to a narrow line strip transformer without extensive discontinuity effects.

3- This type of coupler, due to its natural firmness, doesn't have much tolerance and strong 3-dB coupling coefficient can be reached by that.

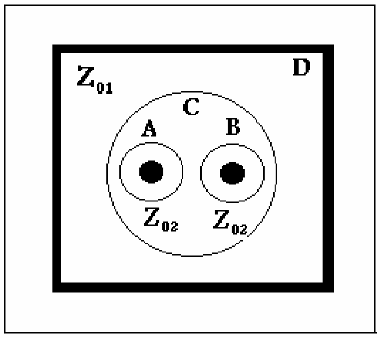

Fig.2. Re-entrant cross section 3db hybrid coupler

The operation of this type of coupler, according to the figure, can be justified as follows:

A and B conductors are the central conductors of the coaxial line with characteristic impedances of Z_{o2} which are located inside of the middle conductor (C). C, on the other hand, forms a transmission line inside of D with the characteristic impedance of Z_{o1}. For analyzing, we use figure 3 and even and odd modes' excitation characteristic impedance as the basis.

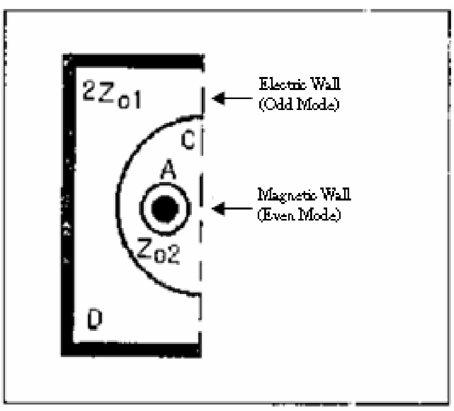

Fig.3. Coupler equivalent circuit while in even and odd modes excitation

Now according to the fact that the created magnetic wall in even mode acts like an open circuit and, moreover, the two impedances are series in relation to each other, we have:

$$Z_{Oe} = Z_{o2} + 2Z_{o1} \quad (5)$$

In odd mode, the electric wall acts like a short circuit and therefore we have:

$$Z_{O0} = Z_{o2} \quad (6)$$

Like the other coupled line coupler types, when there is a full match condition in the input, we can write:

$$Z_0 = \sqrt{Z_{0e}.Z_{O0}} \quad (7)$$

and the coupling coefficient in central frequency will be transformed to the following:

$$K_c = \frac{Z_{0e} - Z_{0o}}{Z_{0e} + Z_{0o}} = \frac{Z_{01}}{Z_{01} + Z_{02}} \quad (8)$$

and also :

$$Z_{0o} = Z_0.\sqrt{\frac{1-K_c}{1+K_c}}$$

(9)

$$Z_{0e} = Z_0.\sqrt{\frac{1+K_c}{1-K_c}}$$

Now according to equation (9) and some further calculations, we have:

$$Z_{01} = \frac{1}{2}(Z_{0e} - Z_{0o}) = Z_0(\frac{K_c}{\sqrt{1-K_c{}^2}})$$

(10)

$$Z_{02} = Z_{0o} = Z_0.\sqrt{\frac{1-K_c}{1+K_C}}$$

After that, by obtaining Z_{01} and Z_{02} and according to figure 4, dimensions of the design can be readily calculated by the following formulas:

$$Z_{01} = \frac{60}{\sqrt{\varepsilon_r}}.\ln\left[\frac{1.0787.D}{d}\right]....(\Omega)$$

(11)

$$Z_{02} = \frac{60}{\sqrt{\varepsilon_r}}.\ln\left[\frac{b}{a}\right]....(\Omega)$$

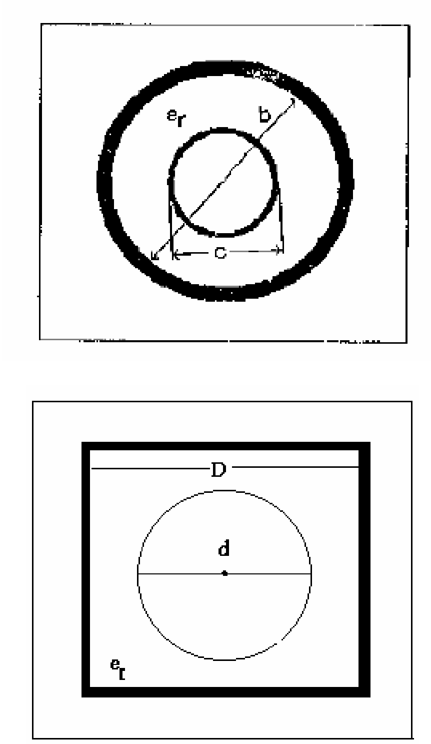

Fig.4. Coaxial line and rectangular coaxial line

The value of D is selected less than 0.1λ to prevent the propagation of higher modes and also keeping the number of discontinuities to a minimum. For designing a 3-dB coupler, if a coupling coefficient of 2.7db (more accurately 2.96db) in the central frequency is considered, with ($3 \pm 0.3db$) coupling, we will have more than one octave of coupling bandwidth. The final point is that the C conductor and A and B internal conductors are fixed inside the ground plane and in the contact edges using Teflon rings which have low reflection.

4-Phase Line and Absorbing Load

The type of appropriate phase line is chosen according to maximum power which the cable can handle (transmitter power) and the cable itself is chosen to cause the least attenuation in the intended frequency band. Then considering the light propagation velocity coefficient in the intended cable (ε_r of the cable dielectric), phase line length can be obtained using the equation 4. The used absorbing load (matched load), is a narrowed resistive load in the shape of what is depicted in figure 5. The resistive material is usually condensed over a hollow dielectric rod (a thin ceramic plate). For the lumped model to remain valid, the following relation should exist: $L \ll \lambda$
For keeping the capacitive effects to minima, resistance layer is designed to be small, to the extent that the mechanical solidity remains in tact. Also the reason why the outer conductor narrows is

keeping the reflection accompanying the attenuation to a minimum [3].

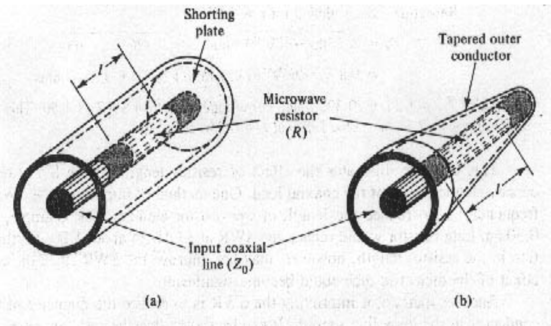

Fig.5. Coaxial narrowed matched load

5-Practical Results

Using a computer program, dimensions and phase line length of a two-way 200W combiner for channels 63 and 66, are obtained as: (characteristic impedance of the design is 50 Ω)

$$f_a = \frac{470+860}{2} = 665 Mhz \qquad l = \frac{\lambda}{4} = 113 mm$$

$$D = 0.085\lambda = 38.3 mm \qquad Z_{01} = 54\Omega$$

$$d = 16.8 mm \qquad Z_{02} = 19.6\Omega$$

$$k = 17.375 \Rightarrow k' = 17$$

$$l_1 = 17 cm \qquad \Delta l = \frac{17c'}{f_2} = 4.03m$$

$$b = 6.94^{mm} \qquad \Rightarrow \qquad l_2 = 4.3m$$

$$c = 5^{mm}$$

The chosen cable according to the information provided in [7] is RG214/U with light propagation velocity coefficient of 0.659. Figures 6 and 7 show the measurements related to separation coefficient between the two inputs and also the frequency response of the lower channel in output. According to the figures, there is 0.8 dB attenuation (inner attenuation) in pass band of each channel. Separation coefficient between the two channels is about 35 dB.

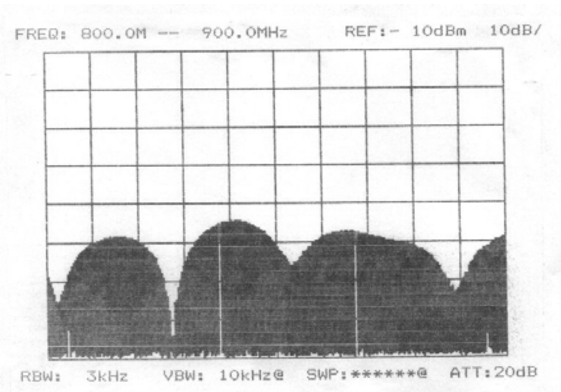

Fig.6. Separation coefficient between the two inputs

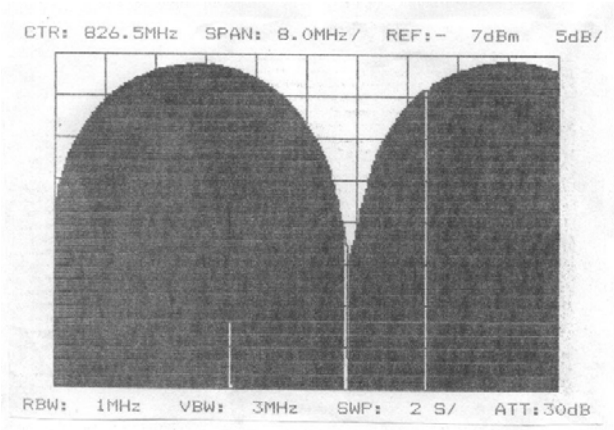

Fig.7. Lower channel output's frequency response

Figures 8 and 9 show the coupling coefficient and directivity for 3-dB coupler designed in UHF band. These figures demonstrate good consistency with design goals. For accurate operation of the device and also interference blocking, input transmitters must have a separation of at least 3 channels between each two of them.

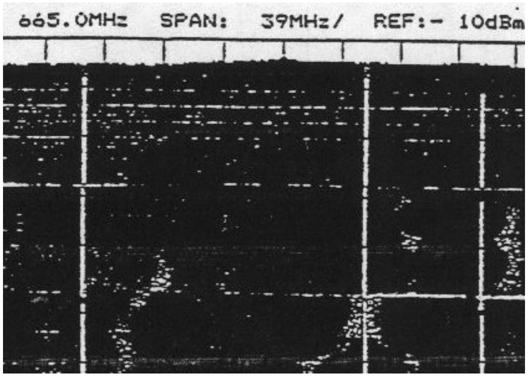

Fig.8. 3-dB coupler's coupling coefficient

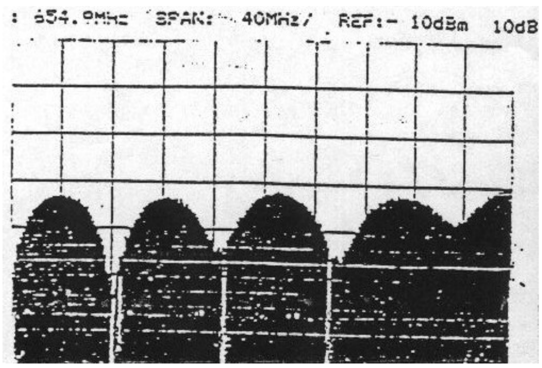

Fig.9. 3-dB coupler directivity

6. Simulation Results:

We also have simulated the device using HPHFSS software package and simulation result compatible by measurement results. In figure 10 structure of directional coupler is shown.

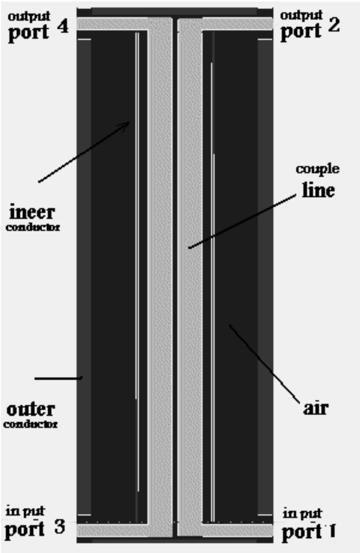

Fig.10. simulated sample directional coupler

In the following figures, coupling factor and Directivity have been shown. Coupling factor for this sample is 3 dB as shown in figure 11 and directivity is about 30 dB.

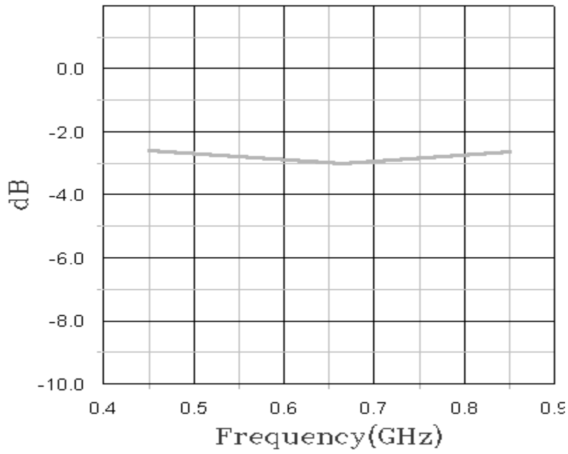

Fig.11. Coupling factor for simulated sample

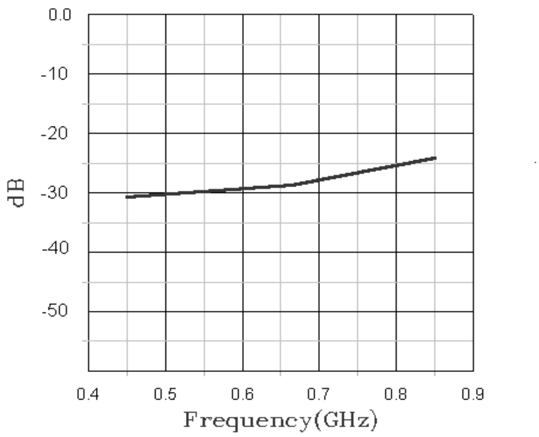

Fig.12. Directivity for simulated sample

Figure 13 shows that return loss of simulated sample.

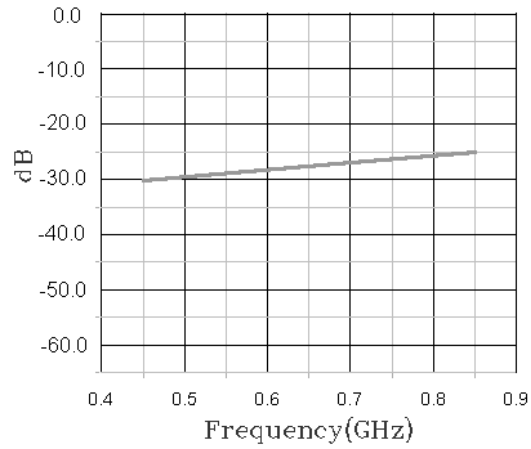

Fig.13. return loss of simulated sample

7 Concluding Remarks

In the phase line combiner approach, it is easily possible to construct a TV combiner using two 3-dB directional couplers, a phase line and an absorbing load. Also there is a possibility to increase the number of inputs to three by using two types of two-way combiners and attaching them together (with required design). The sample constructed device shows satisfactory performance and this approach can be applied to higher powers with slight modifications.

8 Acknowledgements

The authors would like to thank Mr. Kohzadi and Mr. Akbari and also our colleagues at IRIB for the funding of the project and the testing of the constructed sample in their testing facility.

References:

[1] Kathrein catalogue, "Filter, Combiner, Accessories", 2000.

[2] S.B. Cohn, "The Re_Enterant Cross Section $ Wide Band 3 Db Hybrid Coupler",MTT 11, pp. 254-258, July 1963.

[3] P.A.Rizzi," Microwave Engineering Passive Circuit", Printics Hall, 1988.

[4]G. L Matthaei, L. Young, and E. M. T. Jones, "Microwave Filters, Impedance- Matching Networks and Coupling Structures". New York: McGraw Hill, 1988, ch. 13.

[5] G. P Riblet, "A directional coupler with very flat coupling," IEEE Trans. Microwave Theory Terh., vol. MTT-26, pp. 70–74, Feb. 1978.

[6] L. Young, Ed., "Parallel Coupled Lines and Directional Couplers", Dedham, MA: Artech House, 1972.

[7] "Cable Wave Systems Catalogue", 702A, 1991.