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Improving the impedance matching of wideband patch antennas

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Abstract
A narrow impedance bandwidth is the most serious limiting factor of linearly polarized antennas. The problem of designing a wideband antenna is generally studied in the context of loading the antenna with lumped circuit elements. It is a very difficult task to synthesize loaded wire antennas to achieve a broad-band operation, if one chooses to include a matching network, load circuit and the ability to determine proper locations of the load. In this paper a simple and efficient technique for improving the impedance matching of a class of wide band antennas is presented. These antennas have impedance characteristics that exhibit dual (or multiple) resonance. The results obtained are compared between the matched and without matched antennas. This shows the improvement.

Keywords: impedance matching, impedance bandwidth and microstrip antennas

Introduction

One of the possible solutions to the impedance-bandwidth problem consists of introducing dual (or multiple) resonances in the impedance characteristic of the antenna. Typical examples of this bandwidth-enhancement technique are aperture-coupled microstrip antennas with a resonant slot [1], stacked antennas [2], backfire antennas [3], and other types of antennas with similar impedance characteristics.
The basic problem in this class of antennas is the high value of the return loss within the antenna bandwidth. In addition, in antennas with an even number of resonances, the impedance matching is worst at the design (operating) frequency. In this case, the use of a usual (classic) quarter-wavelength transformer improves the impedance matching at the middle frequency, but unfortunately decreases the bandwidth (by more than 30% for an antenna with two resonances).
In this paper we propose a simple and efficient technique for improving impedance matching within the antenna's bandwidth. These antennas have two resonances. We also use a quarter-wavelength transformer to match the antenna to the feed line.

Theoretical analysis

The proposed solution has been applied to a wideband aperture-coupled microstrip antenna that has a resonate slot. This resonate slot has the effect of approximately doubling the antenna's bandwidth, but decreases the impedance matching within the antenna's bandwidth [4]. The patch is responsible for the low-frequency resonance, f_1, and the aperture (the slot) is responsible for the high frequency resonance, f_2. In fact, these two resonance also involve the mutual influence between the patch and the slot.

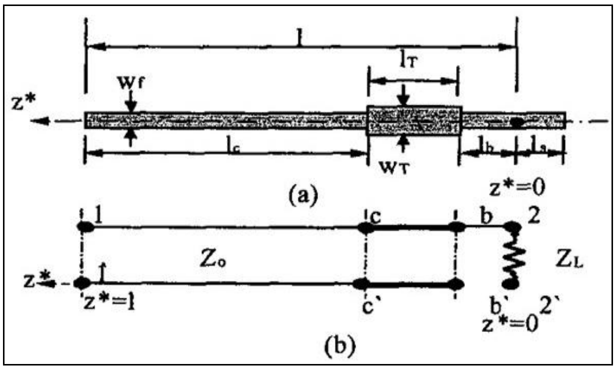

Fig 1

Fig.-1 shows the microstrip feed line and its equivalent circuit. We assume that the origin of the coordinate system is at the point $z^*= 0$ on the line below the patch and the centre of the slot. If the input to the line is at $z^* = l$, the normalized input impedance ($z = r + jx = Z/Z_0 = R/Z_0 + jX/Z_0$) is [5]

$$z = \frac{z_L + \tanh(\gamma l)}{1 + z_L \tanh(\gamma l)} \qquad ...(1)$$

where $z_L = r_L + jx_i$, is the normalized load impedance (the antenna impedance at the point $z^* = 0$), $z_L = Z_L/Z_0$, $r_L = R_L/Z_0$, $x_L = X_L/Z_0$, Z_0 is the characteristic impedance of the feed line, $\gamma = \alpha + j\beta$ is the complex propagation constant, α is the attenuation constant, β is the phase constant, and l is the length of the feed line.

Equation (1) can also be written as follows

$$r = \frac{[r_L M + \sinh(2\alpha l)]Q + [x_L M + \sin(2\beta l)]U}{Q^2 + U^2}$$

$$x = \frac{[x_L M + \sin(2\beta l)]Q - [r_L M + \sinh(2\alpha l)]U}{Q^2 + U^2} \quad \dots (2)$$

Where
$M = \cosh(2\alpha l) + \cos(2\beta l)$,
$Q = M + r_L \sinh(2\alpha l) - x_L \sin(2\beta l)$,
$U = r_L \sin(2\beta l) + x_L \sinh(2\alpha l)$.

If the return loss, $S_{11}(f)$, or the normalized input impedance, z (f), at $z^* = l$ is known (by simulation or measurement), the normalized load impedance in Equation (1) can be expressed as

$$r = \frac{[rM - \sinh(2\alpha l)]A + [xM - \sin(2\beta l)]B}{A^2 + B^2}$$

$$x = \frac{[xM + \sin(2\beta l)]A - [rM - \sinh(2\alpha l)]B}{A^2 + B^2} \quad \dots (2)$$

Where
$A = M - r \sinh(2\alpha l) + x \sin(2\beta l)$,
$B = r \sin(2\beta l) + x \sinh(2\alpha l)$.
The quarter-wavelength transformer must be placed a distance l_b away from the load at point $z^* = 0$, where the input impedance toward the load at $z^* = l_b$ is real. The distance l_b can be found from equation (2)

$$x(l_b) = 0 \dots \quad (4)$$

The same result, but in a closed-form expression, may be obtained for the case of a lossless feed line (a = 0)

$$l_{b1,2} = \frac{\lambda_{g0}}{2\pi} \arctan \frac{(1 - r_{L0}^2 - x_{L0}^2) \pm \sqrt{(1 - r_{L0}^2 - x_{L0}^2)^2 + 4x_{L0}^2}}{2x_{L0}} \dots (5)$$

where
$l_b = l_{b1}, X_{L0} > 0$
$l_b = l_{b2}, X_{L0} > 0$

λg is. the wavelength in the feed line, and the index 0 denotes the mid-frequency, f_0, of the operating frequency range.
The expression used to calculate the characteristic impedance of the quarter-wavelength transformer at $z^* = l_b$ and $f = f_0$ is

$$Z_{0T} = \sqrt{Z_0 R_{b0}} \dots \quad (6)$$

where R_{b0} is the impedance (real, $Z_{b0} = R_{b0}$, $X_{b0} = 0$) of the feed line at $z^* = l_b$ and $f = f_0$.
Accordingly, the impedance matching at $f = f_0$ improves. On the other hand, this leads to a matching degradation at both $f = f_1$ and $f = f_2$.
If the value of the $\lambda/4$ transformer characteristic impedance lies between the values of Z_0 (no transformer) and Z_{0T} (the transformer of equation (6)), the difference between the matching at $f = f_0$ and at both $f = f_1$ and $f = f_2$ will decrease. Thus, the choice of Z_{0T} to fall in this range would improve the impedance matching within the antenna's bandwidth. The antenna matching enhancement would as well lead to an increase of the antenna's gain and efficiency.
We propose to use the following expression to calculate the transformation characteristic impedance, such as

$$Z_{0T} = \sqrt[4]{Z_0^2 R_{b0} \sqrt{R_{b1} R_{b2}}} \dots \quad (7)$$

where R_{bl} and R_{b2} are the impedances of the feed line at $z^* = l_b$ at $f = f_1$ and $f = f_2$, respectively. One may see that in the case where $f_1 = f_2 = f_0$ and $R_{b1} = R_{b2} = R_{b0}$, equation (7) reduces to equation (6).

Results
In order to verify the validity of the proposed solution, we have applied it to a wideband aperture-coupled microstrip antenna [4] in the Ku band. The following parameters were used : the length of the feed line was $l = 26.5$ mm; the width of the feed line was $w_f = 0.972$ mm; the stub length was $l_s = 1.6$ mm; the feed substrate was RT/Duroid 6006, with substrate thickness $h_f = 0.635$ mm; the metal thickness was $t_f = t_g = 0.0175$ mm; the relative dielectric constant was $\varepsilon_{rf} = 6.15$; the loss tangent was $\tan \delta_f = 0.0019$; the characteristic impedance of the feed line was $Z_0 = 50$ ohms; the mid-frequency was $f_0 = 11.822$ GHz; the patch resonant frequency was $f_1 = 11.330$ GHz; the slot resonant frequency was $f_2 = 12.315$ GHZ; the bandwidth was BW = 1.470 GHz (11.08–12.55 GHZ); and the fractional impedance bandwidth was bw = 12.4%.
Finally, the antenna designed with the proposed transformer was fabricated and tested. Fig.–2 shows a graph of the return loss of an aperture coupled microstrip antenna without matching (solid line) and with matching (dashed line). The pair of curves show the improvement.

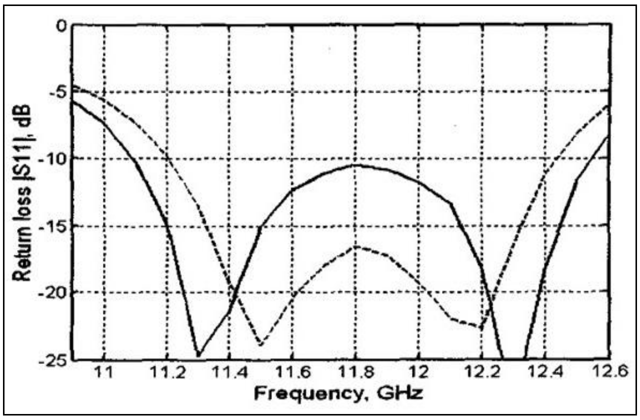

Fig 2

Conclusion
A simple and efficient impedance-matching enhancement technique has been presented. This approach can be carried out using Microwave Office, Math CAD, MATLAB, or even using a programmable handheld calculator. It may therefore be useful for a practical antenna designer.

References

1. Croq F, Papiernik A. Large Bandwidth Aperture-Coupled Microstrip Antenna, Electronics Letters. 1990; 26:1293-1294.
2. Croq F, Pozar DM. Millimeter-Wave Design of Wide-

3. Band Aperture-Coupled Stacked Microstrip Antennas, IEEE Transactions on Antennas and Propagation, AP. 1991; 39:1770-1776.
4. Hristov HD, Kirov GS. Short Backfire Antenna, Certificate of Invention of P.R. Bulgaria NO. 44853, 1987.
5. Kirov GS, Rahman AA, Omar AS. Wideband Aperture Coupled MICROSTRIP Antenna, IEEE International Symposium on Antennas and Propagation Digest, 2, Columbus, Ohio, 2003.
6. Elliot RS. An Introduction to Guided Waves and Microwave Circuits, Englewood Cliffs, NJ, Prentice-Hall Inc, 1993.