From March 2008 *High Frequency Electronics*

Design and Development of Microwave Filters on Metallized ABS Plastic

By Jagdish Shivhare
Institute of Technology and Management

This article is a report on experiments investigating the design and construction of microwave filters using metallized plastic substrates and enclosures

This paper describes experiments to evaluate the use of metallized ABS plastic in place of metal and other substrates for cavity and planar structure communication filters, which can reduce the weight and cost. The specific gravity of ABS plastic is 1.05 gm/cm^3 compared to 2.7, 8.5 and 8.9 gm/cm^3 for commercial aluminum, brass and copper respectively. The cost of metallized ABS plastic substrate may be substantially less than the cost of traditional microwave laminates such as Rogers RT-Duroid. Some cavity bandpass filters have been developed and tested at center frequencies of 53.5 ±1.5 MHz, 86.5 ±4 MHz, 324 ±4 MHz, 600 ±9 MHz, 1200 ±150 MHz, 1537.5 ±7.5 MHz, 1636 ±10 MHz, 4190 ±20 MHz, 4590 ±20 MHz and 5.850-5930 GHz. Two-hairpin line filters at 1537.5 ±10 MHz and 1575.5 ±10 MHz, also have been developed and tested [1].

Introduction

Although there have been other efforts to use metallized plastic, metal remains the material universally used to make cavity filters, while PTFE laminates dominate microstrip and stripline filter designs. Therefore, their manufacturing cost is high. The electrical characteristics of ABS plastic show minor changes at normal operating temperature, humidity and frequency, and the dielectric properties are sufficiently good. ABS plastic exhibits a flat module curve over a wide temperature range. Dimensional tolerance can be maintained within 0.003 mm. Machining characteristics are similar to those of non-ferrous metals. The plastic may be drilled, punched, die-cut, routed, sawn and turned. Favorable electrical, mechanical, physical and environmental properties may increase its applicability as an alternative to metal to fabricate precise filters such as helical, combline, interdigital and coaxial cavity band pass filters in different frequency ranges. The ABS plastic may be used in place of PTFE substrate for planar structures [2].

The performance of two hairpin line (microstrip) band pass filters at 1537.5 MHz and 1575.5 MHz have been verified with the help of standard filters. The achieved insertion loss is high due to the higher dissipation factor of ABS. The insertion loss can be reduced to approach the loss of soft PTFE substrate (RT-Duroid # 5870, 1.58 mm thick with dielectric constant of 2.32) by doubling the thickness of ABS plastic sheet. However the 3 dB bandwidth is also doubled. So, if this compromise between insertion loss and bandwidth is an acceptable criterion, very low cost hair pin line filters may be developed by using the ABS plastic in place of a PTFE substrate [3].

Design Procedure

The existing design theory for any type of cavity band pass filter is applicable. No correction in design is required while using ABS plastic in place of metal. However, a few graphs have to be generated to use the ABS plastic as a substrate for hairpin line structure. Here, the design theory available for RT-Duroid #5870, of dielectric constant 2.32 and thickness 1.58 mm has been used to calculate the dimensions of a hair pin line band pass filter [4].

Established design procedures and tables for any type of cavity, helical, combline, inter digital, coaxial cavity filters may be utilized. Similarly, design procedures available for planar structures such as parallel coupled, hairpin line band pass filters may be used [1, 2, 3]. Figures 1 and 2 show the results for the microstrip hairpin filters noted above. Additional results for other types of filters are shown in Figures 3 through 6.

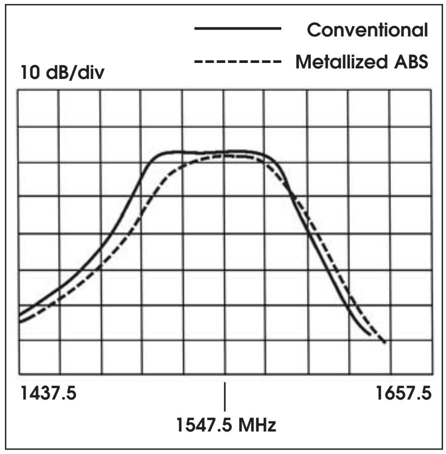

Figure 1 · Measurement of the 1537.5 MHz hairpin filter.

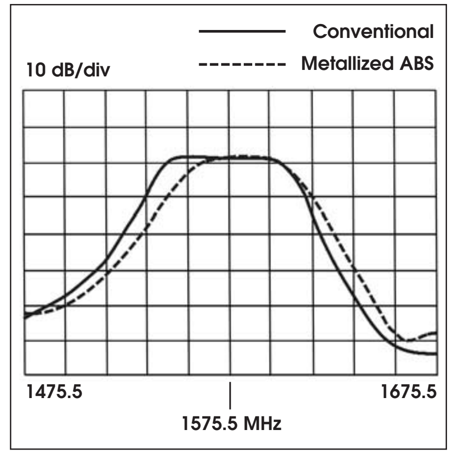

Figure 2 · Measurement of the 1575.42 MHz hairpin filter.

Important Properties of ABS

The electrical characteristics of ABS plastic show minor changes with temperature, humidity and frequency. The dielectric properties are sufficiently good to be considered for a number of electrical applications. ABS exhibits a flat modulus curve that varies only slightly over a wide temperature range. It exhibits high impact strength values. Good impact figures are maintained even at temperatures as low as –40º C. Unlike other thermoplastics, it is not significantly affected by variation in strain rate.

ABS plastic is resistant to weak acids and inorganic bases, although concentrated nitric and sulphuric acid produce disintegration. It is also swelled, softened or dissolved by most of the low order aromatics, ketones, esters etc. ABS plastic can be metallized, therefore an enclosure made of metallized ABS plastic

$$(\epsilon\,eff)^{1/2} = \frac{\text{Difference of electrical length i.e. (EL150-EL50)}}{\text{Difference of physical length i.e. (150-50)}}$$

Frequency of measurement in MHz	RT.DUROID #5880				ABS-PLASTIC # AP78 EP			
	Measured Electrical length in (mm) for		ϵ eff	ϵ eff	Measured Electrical length in (mm) for		ϵ eff	ϵ eff
	150mm physical length of 50 Ohm line	50mm physical length of 50 Ohm line			150mm physical length of 50 Ohm line	50mm physical length of 50 Ohm line		
45.0	230.76	96.26	1.345	1.81	231.22	93.82	1.374	1.89
650.0	232.18	96.18	1.360	1.85	233.15	95.35	1.378	1.90
1500.0	234.49	97.79	1.367	1.87	234.61	95.71	1.389	1.93
2500.0	235.82	97.62	1.382	1.91	235.70	95.40	1.403	1.97
4500.0	236.75	97.15	1.396	1.95	237.14	96.14	1.410	1.99
7000.0	242.11	97.91	1.442	2.08	250.32	108.22	1.421	2.0
10000.0	251.43	106.53	1.449	2.10	263.07	117.47	1.456	2.1
From DATA sheet of ROGERS CORP,USA. Er=2.22 ± 0.02, up to 10GHz. ϵ eff=1.89 for 50 ohm line. Dissipation factor: 0.0009. Measured ϵ eff is approximately equal to actual ϵ eff (1.89). Which verifies correctness or our test method of measurement. (Table-2)					From DATA sheet by ABSTRON Er=(2.8 – 3.3) at 1MHz. ϵ eff (measure) =1.89-2.12 for 50 ohm line from 45MHz to 10GHz. Dissipation factor: 0.0024 at 9.0GHz. Measured by wave guide method with 19x19x3 mm^3 sheet of ABS plastic.			

Table 1 · Network analyzer measurement of ε_{eff} of ABS plastic.

VERIFICATION OF CORRECTNESS OF OUR TEST METHOD

S.No.	For RT-DUROID # 5880 T ROGERS CORP. USA	For ABS-PLASTIC # AP78EP ABSTRON INDIA
01.	Thickness of substrate: 1-6mm	Chosen thickness for filters: 1-6mm
02.	As per DATA sheet: ϵ eff=1.89 for 50 ohm line upto 10GHz	Measured ϵ eff=1.89 to 2.12 from 45MHz – 10GHz
03.	Length of resonator ($\frac{\lambda}{4}$) at 1537.5 MHz & 1575.42MHz $\frac{\lambda}{4}=\frac{3\times10^{11}}{4\times1537.5\times10^{6}\sqrt{1.89}}$ =35.628 at 1537.5MHz $\frac{\lambda}{4}$=34.483 at 1575.42MHz	Practically (found) lengths of hairpin line resonators are 31.0mm and 32.0mm at center frequencies 1537.5 & 1575.42 respectively. Therefore, $\sqrt{\epsilon_{eff}}=\frac{3\times10^{11}}{4\times1537.5\times10^{6}\times(\frac{\lambda}{4})}$ = 1.96 at 1537.5 MHz and 1.94 at 1575.42MHz.
04.	By our test method, ϵ eff =1.87 at 1500MHz and varies form 1.89 to 2.12 for 45MHz to 10GHz. Thus the measured values of ϵ eff are very close to the actual ϵ eff (1.89 for 50 ohm line), which verifies the correctness of our test method.	By the same test method, ϵ eff =1.93 (Table-1) for which is very close to the values found practically, ϵ eff=1.94 & 1.96 at 1537.5MHz & 1575.42MHz. This also provides the proof of the correctness of our method adopted for measurements of ϵ eff.

Table 2 · Summary of test methodology.

behaves electrically in a similar manner as the metallic enclosure.

ABS with 10% Butadine is more suitable for electroplating than ABS with 16 to 27% Butadine. Several trials were conducted for electroplating on ABS plastic. The articles are immersed in a mixture of chromic and sulphuric acid to improve mechanical adhesion. Poor etching leads to skip plating or poor adhesion of the plate and possible blistering. Thus, etched articles are to be treated with sensitizer and activators, Stannous chloride and palladium chloride solutions are used for this purpose. The deposited palladium nuclei on the plastic surface initiates electroless plating of copper, nickel, gold or other metals.

We carried out electroless copper deposition for our work. The purpose of plating on ABS is to get highly conductive coating. For this, it is finally deposited with electroplated copper and silver.

Type of filter	Freq. Band MHz	Center Freq. MHz	Band width MHz	Insertion loss dB	I/O return loss dB	Stop band attenuation dBc	Size (LxBxH) MMxMMx MM	Weight grams
VHF/UHF								
Helical	52-55	53.5	±1.5	1.0	16	30dBc @60MHz	200x50x72	80
Helical	85-88	86.5	±1.5	1.0	16	30dBc @80MHz	200x50x72	80
Helical	320-328	324.0	±4.0	6.0	15	>30dBc @±8MHz	105x38x25	41
Helical	591-609	600.0	±9.0	2.2	20	>30dBc @±18MHz	100x23x33	28
Combline	1050-1350	1200.0	±150	1.5	15	>30dBc @±300MHz	155x45x30	55
L-BAND								
Co-axial	1530-1545	1537.5	±7.5	0.4	20	>30dBc @±90MHz	130x44x37	90
Co-axial	1626-1646	1636.0	±10	0.4	20	>30dBc @±90MHz	152x52x41	130
S-BAND								
Combline	2500-2690	2595.0	±85	1.5	16	>30dBc @±2000MHz	120x25x20	110
C-BAND								
Combline	4170-4200	4190.0	±20	1.5	15	>30dBc @±40MHz	107x21x18	30
Combline	4570-4610	4590.0	±20	1.5	15	>30dBc @±40MHz	126x23x17	40
Combline	5850-5930	5890.0	±40	2.0	16	>30dBc @±80MHz	95x18x12	50
Ext. C-BAND								
Combline	6725-7025	6835.0	±150	2.0	15	>30dBc @±500MHz	100x11x13	100

Table 3 · Design and fabrication details of the microwave bandpass filters.

Conclusion

A number of cavity and microstrip band pass filters have been tried up to 6 GHz. The performance of the cavity as well as the microstrip filters also were tested over the temperature range of –20ºC to + 60º C, with a minor shift in the center frequency without affecting bandwidth and stopband attenuation. It has been noticed that the shift in the frequency depends upon the size and structures of the filters. In particular, at the higher frequencies, the size of the fingers in combline filter is very small, which increases the shift in center frequency. But, it is less than the commercial aluminum body filter. In general, electronic performance is fully satisfactory, but mechanical performance requires further improvement.

Editor's note—Original plots were not available to the author. The re-drawn figures are not precise, but show the general shape of the filter responses.

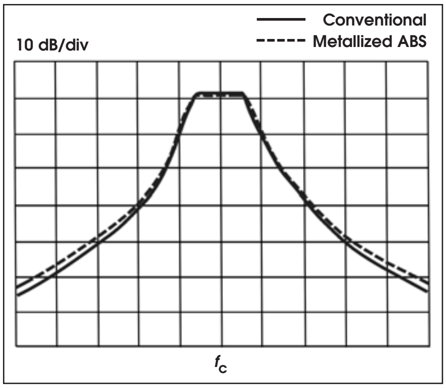

Figure 3 · Bandpass plots for the 1537.5 MHz coaxial cavity filter.

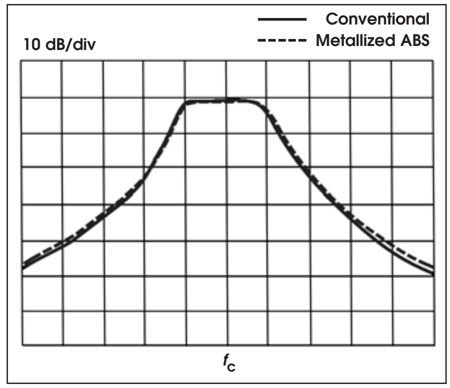

Figure 4 · Bandpass plots for the 1636.0 MHz coaxial cavity filter.

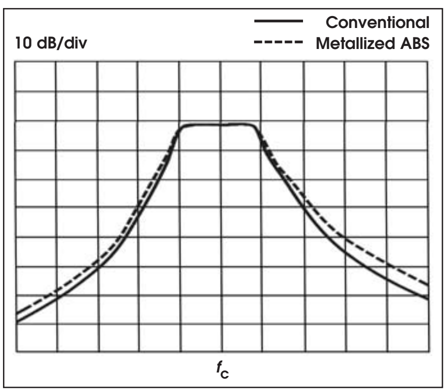

Figure 5 · Bandpass plots for the 600 MHz helical filter.

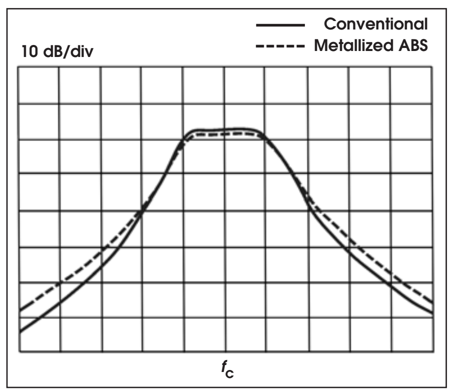

Figure 5 · Bandpass plots for the 4190 MHz combline filter.

Acknowledgement

The author wishes to acknowledge the assistance and support of the technical staff of the Institute of Technology and Management, Gurgaon, India.

References

1. Zerev A. I., *Handbook of Filter Synthesis*, John Wiley and Sons, New York,1967.

2. A. I. Atia and A. E. Willand, "Inter-cavity Coupling," *IEEE Proc. MTT*, vol. 23, no.6, p.519-521, June 1975.

3. Robert F. Arneseri, "Coupling Loops/Tapping Positions for Cavity Band Pass Filters, *Microwaves & RF*, November 1986.

4. G. L. Matthaie et al, *Microwave Filters, Impedance Matching and Coupling Structures*, Dedham, MA, Artech House, 1980.

Author Information

Mr. Jagdish Shivhare joined the Institute of Technology and Management (ITM), Gurgaon, India, in 2003, after his retirement from the Indian Space Research Organization (ISRO). At ITM, he is Chairman of the Society of Electronics Engineers (SEE), Faculty Coordinator of ISTE and in charge of student-related activities. During his 20 years of service at ISRO, he was actively involved in R & D projects for ground and space applications. He has designed and developed devices such as high temperature superconductive filters, sub-systems and systems for different types of receiving terminals, earth stations and communication satellites such as ISTRAC, DRS, TVRO, IMESS, INSAT, INMARSAT, GPS, and Radio Astron. Mr. Shivhare can be reached by e-mail at: jshivhare.isro@gmail.com