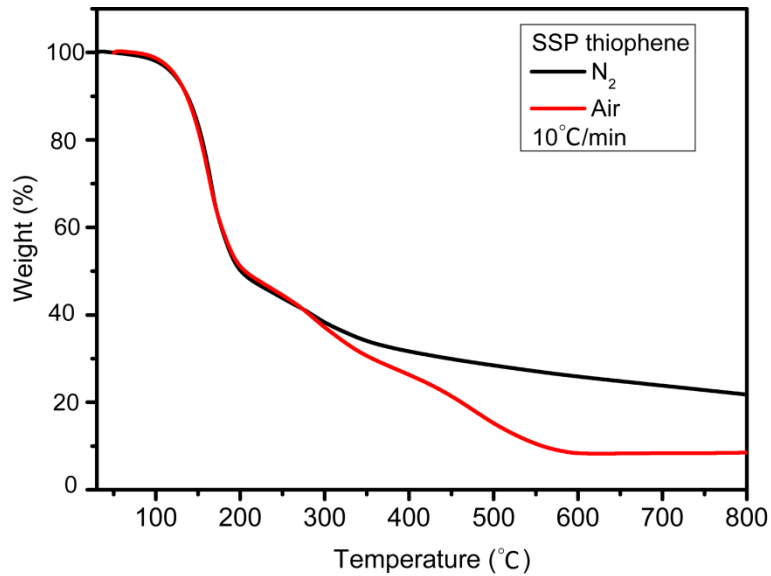SI Figure 1. XPS spectra of SSP-PEDOT with different heating time of 1 h (a), 2 h (b), 4 h (c), 8 h (d), 12 h (e) and 48 h (f).

SI Figure 2. TGA curves of the DBEDOT at the heating scan of 10°C/min under nitrogen and air flow.
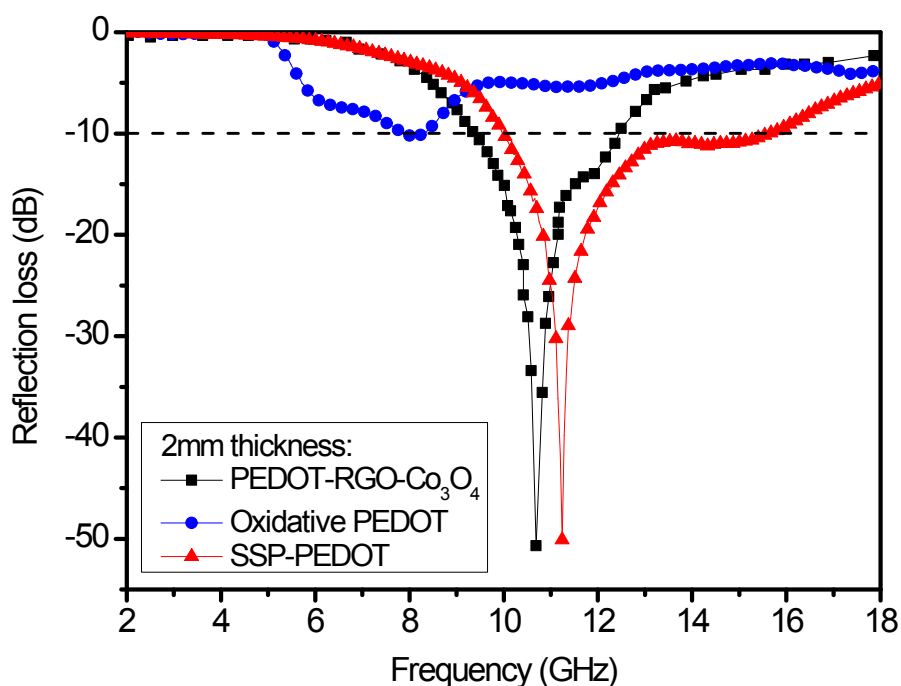
MATLAB program:

```
n=size(data)
n=n(1)
f=data(:,1);
e1=data(:,2);
e2=data(:,3);
u1=data(:,4);
u2=data(:,5);
d=0.002
c=300000000;
for ii=1:n;
    y(ii)=((u1(ii)-i*u2(ii))/(e1(ii)-i*e2(ii)))^0.5
    yy(ii)=((u1(ii)-i*u2(ii))*(e1(ii)-i*e2(ii)))^0.5

    r(ii)=2*pi*f(ii)*d/c*yy(ii)*i;
    rr(ii)=y(ii)*sinh(r(ii))/cosh(r(ii));
    rrrr(ii)=(rr(ii)-1)/(rr(ii)+1);
    rrr(ii)=20*log10(abs(rrrr(ii)));
end
plot(f,rrr)
```

SI Figure 3. PEDOT-RGO-Co$_3$O$_4$ has a bandwidth exceeding −10 dB about 3.1 GHz (ACS Appl. Mater. Interfaces, 2013, 5, 12355); oxidative polymerized PEDOT has a poor absorption 6 to 9 GHz; SSP-PEDOT has a bandwidth exceeding −10 dB about 5.9 GHz. All samples were mixed with paraffin as the weight ratio of 1 : 1.

Synthesis of oxidative poly(3,4-ethylenedioxythiophene). 0.9 g of anhydrous ferric chloride (FeCl$_3$) and 0.4 g of EDOT was dispersed in 25 mL of distilled water, respectively. Then the solution of FeCl$_3$ was dropped into the dispersion of EDOT with intensive stirring, and the temperature was heated to 95 °C for 24 hours. The dark blue solid product was purified using filtration with hydrochloric acid (2 times) and distilled water (3 times). Finally, 0.46 g of oxidative PEDOT was obtained after vacuum drying under 50 °C for 12 hours.